Reports

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Sexual Dimorphism in Shrimp. Subjects: Life Science / Biology Grades: 9-12

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SEXUAL DIMORPHISM IN SHRIMP

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Grade Level
Advanced High School (AP/IB)

Subject area
Biology

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1. Activity Title: Sexual dimorphism in snapping shrimp

2. Focus: Test predictions of sexual selection on snapping shrimp chela allometry

3. Grade Levels/ Subject: 11-12th grade Life Science, HS Biology, AP Biology, IB Biology

4. VA Science Standard(s) addressed:

BIO 1b) Hypotheses are formulated based on direct observations and information from scientific literature

BIO 1c) Variables are defined and investigations are designed to test hypotheses

BIO 1d) Graphing and arithmetic calculations are used as tools in data analysis

BIO 1e) Conclusions are formed based on recorded quantitative and qualitative data

BIO 7c) How natural selection leads to adaptations

AP Biology:

LO 1.2) The student is able to evaluate evidence provided by data to qualitatively and quantitatively investigate the role of natural selection in evolution

LO 1.5) The student is able to connect evolutionary changes in a population over time to a change in the environment.

LO 1.11) The student is able to design a plan to answer scientific questions regarding how organisms have changed over time using information from morphology, biochemistry and geology.

IB Biology:
5.4.7) Explain how natural selection leads to evolution

5. Learning objectives/outcomes: Students will:

a. Explain why many animals are sexually dimorphic
b. Distinguish between natural and sexual selection
c. Make prediction based on a broad hypothesis
d. Develop alternative hypothesis when original hypothesis fails.
e. Use excel for t-test
f. Integrate math/stat in hypotheses testing

6. Total length of time required for the lesson

- Part I: 80 min (introduction, pre-lab questions, measurement)
- Part II: 80 min (statistics review, data analyses, conclusion)

7. Key words, vocabulary: Eusociality, snapping shrimp, chela, carapace, allometry, t-test, linear regression, natural selection, sexual selection, sexual dimorphism, secondary sexual characters, allometry (Use electronic copy for web links or refer to PowerPoint).

8. Background information: Lesson background and procedures are outlined within the PowerPoint: "Snapping shrimp dimorphism slides.pptx". Note are available for most slides. Questions to engage students are marked with "QQQ"

9. Student handouts and other materials needed

Distribute to students:

- Snapping shrimp worksheet.docx
- ImageJ Instructions.docx (optional, day 1)
- A folder called "S.yano pictures" with pictures of carapace and chela (day 2)
- Eusocial_species_morphometric_S.regalis.xlsx (day 2)

For instructor use only:

- Snapping shrimp dimorphism PPT slides.pptx (**instructor can follow this PowerPoint for the entire lesson plan**)
- Communal_species_morphometric_S.yano.xlsx
- Eusocial_species_morphometric_S.regalis_with_t_test.xlsx (**t-test demonstration for instructor, see reference below for video demonstrations**)

10. Materials & Supplies, A/V/Tech Support:

Download *ImageJ* free from: https://imagej.nih.gov/ij/download.html.

- For Macs, download the "ImageJ 1.49 (6MB) as a double-clickable Mac OS X application."
- For PC, download the "ImageJ 1.49 bundled with Java 1.6.0_24 (37MB)".

NOTE: ImageJ works on a computer with Java pre-installed. If you do not have Java on your computer, be sure to download a version labeled as "ImageJ bundled with Java…"

What is ImageJ Software and What Does It Do?

For a brief summary, see: https://en.wikipedia.org/wiki/ImageJ

For information from the U.S. National Institutes of Health (NIH), see: https://imagej.nih.gov/ij/. For an introduction, click the "Documentation" tab and see "Introduction" for a description of the functions of Image J and see "Basic Concepts" for visual examples. There is information about "Installation," an "ImageJ User Guide," plus tutorials and examples. The User Guide is highly recommended as a place to start, it is downloadable as a PDF from the NIH website.

✱Important Operating Notes✱

* It's best to distribute the software and pictures through a shared network drive. This way, students will not need to download and unzip and program, which will take a long time.

** **If IT security or available time prevent the use of the ImageJ program,**

the instructor could skip the ImageJ activity and either:

1) Distribute the data in "Communal_species_morphometric_S.yano.xlsx" for students to analyze. Or,

2) Print the pictures and use rulers to do the measurements.

11. Classroom/Lab/Field Study Setup: One computer per team of 2 or more students. The ImageJ software and pictures can be preloaded onto the computers or distributed during class time with a thumb drive/ shared folder.

12. Procedure:

A. Day 1

➤**(Engage) Introduction to sexual dimorphism and study organism**

PPT Slides part A – 10 minutes

- Introduce the prevalence of sexual dimorphism
- Review the basis of natural selection, emphasize the **variation** in a trait and **differential reproduction** of certain trait.
- Introduce sexual selection that explains sexual dimorphism. Similarly, emphasize the need for variation and differential reproduction to produce a sexually selected trait. The key of sexual selection is that the cause of differential reproduction and the scale it operates are different from natural selection.
- Introduce snapping shrimps: Communal species has high potential for sexual selection to be operating

➤**(Explore 1) Set hypothesis and predictions**

Worksheet part I and II. Backgrounds and pre-lab question – 10 minutes:

- Remind students of the main hypothesis: *Sexual selection is operating in snapping shrimps*, and that many predictions (or specific hypotheses) can be drawn from a main hypothesis.
- Q1. i) Engage student to make predictions:
  - *Snapping shrimps are sexually dimorphic. Specifically, chela sizes are larger in males than females.*
- Q1. ii) Engage student to set out a procedure to test the predictions:
  - *Compare mean chela size of males and females, etc.*
  - NOTE: The above is expected to be the most common answer, but it's not going to work. We'll explore the data below and work out a better way to test the prediction.
  - Encourage students to think about what statistical test can be used.

- Q2. ii) Practice describing patterns verbally and mathematically.
  - Note that the scales are in log.
  - The data show clearly that chela length increases with carapace length. Therefore, merely comparing either chela length or carapace length is not a fair comparison.
  - To illustrate this, discuss arm length of males versus females in human and the need to control for height.
- Q2. iii) Let students discuss how to refine their predictions:
  - *Compare the mean 'relative' chela size (chela size divided by carapace length) between males and females.*
  - Alternatively*: calculate the slopes of the allometry from males and females – we will not use this approach here*

➢**(Explore 2) Activity: Morphometric measurements**

Worksheet part II. Morphometric measurements – 45 minutes:

- Divide students into groups of >2. Each group will share a computer; distribute ImageJ and pictures
- Demo the usage of ImageJ according to "ImageJ Instructions.docx"
- Use slides Part B or ImageJ to demonstrate the correct way of measuring carapace and chela lengths
- (Alternatively, have students read "ImageJ Instructions.docx" themselves)
- Allow students to work on measurements
- Pool data and re-distribute final dataset to students in the next class (*** It's essential that students enter their data in the same format to combine data. If possible, have students enter data into a shared spreadsheet, e.g., Google Document Sheet)

➢**Optional/ take-home task: Statistics Review**

Worksheet part III. Statistics Review – 10 minutes

- Review the basis of t-test basis and demonstrate Excel's t.test command

B. Day 2

➢**(Explain)**

Worksheet part III. Statistics Review – 10 min

- Review/ demonstrate excel procedure for t-test
- Demonstrate two ways of plotting data as illustrated in "Communal_species_morphometric_S.yano.xlsx" or "Eusocial_species_morphometric_S.regalis_with_t_test.xlsx"
  - Figure 1: Bar plot comparing the mean
  - Figure 2: Bar plot comparing the distribution of relative claw sizes of males and females

Worksheet part IV. Data Analysis – 30 min

- Student work on data analysis and discuss results

PPT Slides part B – 10 min

- Introduce eusocial shrimps and show BBC video.

➢**(Elaborate)**

Worksheet part V. Further Analysis – 30 min

- Students in the same groups work on data analysis with eusocial species provided in "Eusocial_species_morphometric_S.regalis.xlsx"
- Discuss hypothesis for not seeing sexual dimorphism in eusocial species
- Wrap-up using real published data in the PowerPoint slide

➢**(Evaluate)**

Worksheet part VI. Challenge question (Assessment) – 30 min

- Present cases of reverse sexual dimorphism
- Students discuss and come up with hypothesis, predictions and experiments.
- http://onlinelibrary.wiley.com/doi/10.1111/j.1469-185X.1990.tb01238.x/abstract
- http://link.springer.com/article/10.1007%2Fs10682-005-0293-9
- http://www.avesvitae.org/avesvitae/Featured_Species/Entries/2012/1/17_Phalaropes__Breeding_roles_turned_upside_down.html

13. Assessment: See Worksheet part VI. Challenge question

14. References:

ImageJ
Video instruction for measuring length

T-test

Video introduction

Video demonstration of t.test function in excel

Natural selection
Understanding Evolution website

Sexual selection

Brennan, P. (2010) Sexual Selection. Nature Education Knowledge 3(10):79

Hosken, D. J., and C. M. House. 2011. Sexual selection. Current Biology 21:R62-R65.

Reduced sexual dimorphism in social animals

Clutton-Brock, T. H., S. J. Hodge, G. Spong, A. F. Russell, N. R. Jordan, N. C. Bennett, L. L. Sharpe et al. 2006. Intrasexual competition and sexual selection in cooperative mammals. Nature 444:1065-1068.

Rubenstein, D. R., and I. J. Lovette. 2009. Reproductive skew and selection on female ornamentation in social species. Nature 462:786-789.

Chak, S. T. C., J. E. Duffy, and D. R. Rubenstein. 2015. Reproductive skew drives patterns of sexual dimorphism in sponge-dwelling snapping shrimps. Proceedings of the Royal Society B: Biological Sciences 282:20150342.

Reverse sexual dimorphism

Mueller, H. C. 1986. The Evolution of Reversed Sexual Dimorphism in Owls: An Empirical Analysis of Possible Selective Factors. The Wilson Bulletin 98:387-406.

Mueller, H. C. 1990. The evolution of reversed sexual dimorphism in size in monogamous species of birds. Biological Reviews 65:553-585.

Krüger, O. 2005. The Evolution of Reversed Sexual Size Dimorphism in Hawks, Falcons and Owls: A Comparative Study. Evolutionary Ecology 19:467-486. Size and Sex in Raptors

Wilson, C.A. et al. 1991. An examination of sexual dimorphism in Atlantic and Pacific blue marlin using body weight, sagittae weight, and age estimates. Journal of Experimental Marine Biology and Ecology Vol 151 (2): 209-225.

Kopf, R.K., et al. 2012. Reproductive biology and spatiotemportal patterns of spawning in striped marlin *Kajikia audax*. Journal of Fish Biology Vol. 81 (6): 1834-1858.